

What is (the) observable ?

LARSIM-ESNT workshop

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I. OBJECTIVES

The objectives of the workshop series co-organized by the Laboratoire de Recherche sur les Sciences de la Matière (LARSIM) and the Espace de Structure et réactions Nucléaires Théorique (ESNT) is to conduct a long-term reflection on the epistemological undertaking and the practice of scientific research.

The subjects dealt with in the LARSIM-ESNT workshops since 2013, the details of which are available on the esnt.cea.fr website, have, among other things, led to a gradual reflection on the nature of physical objects, theories and models that attempt to describe them and the limits of the representations that physicists impose, in a more or less explicit and conscious way, on nature.

In this context, the sixth edition proposes to question and deepen the notion of observable and the way in which it intricates the theoretical underlying and the experimental measurement by means of "phénoménotechniques" tools.

II. CONTEXT AND RATIONALE

Natural sciences are built, from Galileo, according to the adequacy between predictions derived from a theory and the results of experiments or observations. However, the understanding of contemporary science should not be reduced to the old positivist model, where physics and mathematical sciences consisted only of a passive correspondence between the measure of directly observable phenomena and the prediction of laws that could be induced from their regularity. The search for fitness in physics is in itself a process whose modalities are to be questioned, especially as regards effective theories. Should we always postulate the existence of an unambiguous correspondance between the application of physical theories on the one hand, and, on the other hand, the experimentally produced observables?

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The attention paid to the possibility of such a focus raises the issue of its conventional nature and the possible methodological biases underlying its implementation.

It can be noted that this comparative process is based on the elaboration, at the outset complex and dialectic, of the domain of validity of a physical theory and of what is fundamentally observable in a phenomenon. While one could naively consider that the definition of theoretical structures and entities can develop on parallel and independent paths, it should be stressed that the search for a physical observable does not only question the "phenomenon in itself", but its profound nature and the ability of man to highlight it among other elements considered secondary. Because the mathematical structures developed within a theory induce, in a more or less explicit and binding way, what is actually observable by means of observational and experimental devices.

The notion of observable thus appears immediately as a conceptual interlacing of theoretical and technical constraints. First of all, the characterization of an observable cannot be isolated from the determinations derived from the process used to highlight it; e.g. from the observer standpoint or the experimental and computational procedures used to extract the observables. On the other hand, the assumptions and the theoretical framework, the specificity of the relevant mathematical operators and the choice of the degrees of freedom of the physical system, select and structure the observational and experimental mechanisms. From this epistemological entanglement, neither abstract nor peremptory conclusions should be drawn as to the conventional nature of the notion of observable. Such a problem only delivers its meaning when it is itself analyzed and objectivized within a discipline. The words of Gaston Bachelard may be used in this regard when he speaks of a discipline in action as a "region" of applied rationalism.

The recommendation to grasp the observable at the time of its own effectivity along with the intrication it entertains with the theoretical framework of its emergence is all the more indispensable as this notion risks to disappear through semantic translation whenever producing the final interpretation of the results. Indeed, the critical and quantitative analysis of observations with the aim of supporting, corroborating, clarifying, rectifying or invalidating a physical theory cannot be carried out without a precise definition of what an observable stands for, without running the risk of a major methodological misconduct. The need to critically and recurrently control the role of the observable, its function and its field of relevance, becomes crucial whenever a risk of regression, more or less voluntary and conscious, towards a positivism forgetting, or at best neglecting, the dependence of the result of the comparison between theory and experience with respect to the choice of observable arises.

This risk is obvious and clearly identified in quantum mechanics, where the role of the observer and the choice of specific (i.e. linear and self-adjoint) operators acting on the Hilbert space of possible physical states constitute a methodological process restricting the possible definition of an observable. Still, the evolution of the experimental endeavor and the massive use of diagrammatic representations in the development of quantum field theories, have helped to conceal the conventional and intricate nature of observable in the light of the theories they are derived from. One can, for example, recall in this regard the confusion sometimes generated by the use of Feynman diagrams through which the classical concept of trajectory resurfaced as a qualifier of an amplitude that is only the condensation of a field Quantum.

To provisionally illuminate the status of the observable inscribed in any interpretation of the experiments, one can use the heuristic structure of the "semiotic triangle". The latter, designed for the semantics of language, describes the dimensions of the meaning by distinguishing the sign, the referent and the reference. In the case of observable, the sign resides, especially in physics, in the mathematical formalism that expresses the notion of operator and is readily identifiable with a self-consistent and unambiguous mathematical definition. The referent, meanwhile, is more associated with the observer's function, whose technical and interpretative constraints influence his ability to accurately access the sign as an abstract mathematical operator. Finally, the reference raises the issue of the ontological correlate of observation and its interpretation as a questioning of the existence and accessibility of properties of nature whose observable would be the expression.

With this minimal translation of the multiple semantic orientations of the notion of observable, we propose to present and question its foundations and its epistemological evolution, to analyze certain implications for contemporary experimental, theoretical or diagrammatic tools, but also to sketch comparisons with other disciplinary fields such as history, musicology, art, linguistics or knowledge management. Like the previous editions of the LARSIM-ESNT workshops, this week-long seminar is aimed at theoretical and experimental physicists, irrespective of their knowledge and or their training in philosophy of science. The progressive and participatory nature of the workshop allows all the participants to evolve in the reflection in a marked and personal way, while nourishing the suggestions and the experience of the other participants.

III. GOALS OF THE WORKSHOP

In summary, the objectives of the workshop can be expressed as follows

1. Questioning the notion of observable, its origins, its field of application and validity in physical sciences

2. Nourishing the reflection on the relationship between the notion of observable and that of observer, observation and operator
3. Provide interpretative keys and methodological suggestions in comparing experimental results and theoretical predictions associated with physical observability
4. Continue the long-term collaboration between LARSIM and ESNT, particularly regarding the foundations and practices of research

IV. PROGRAM

- **First part : The paradoxical progress of the observations**

1. Observable; facts and swans [V. Bontems, philosopher]
2. The Quantum Revolution: Measurement and interaction [E. Klein, philosopher]
3. Phénoménoteknik and observable [V. Bontems, philosopher]
4. Euclid : discovering black from black [M. Sauvage, physicist]

- **Second part : Quantum operators and observables**

1. First part
 - Reduction and explanation in physics [J. Rosaler, philosopher]
 - From observables to generalized parton distributions in hadron physics [H. Moutarde, physicist]
 - Symetries and mathematical surplus [J. Ladyman, philosopher]
 - Observable and quasi-observable in the nucleon's spin analysis [C. Lorcé, physicist]
2. Second part
 - Theory of measurement in Quantum Mechanics [R. Balian, physicist]
 - What is a quantum observer ? [A. Grinbaum, philosopher]
 - The lesson of quantum entanglement: "event" and "system" as substitutes for the notions of "object" and "observable". [G. Mauro d'Ariano, physicien]
 - Observables, Disassembled [B. W. Roberts, philosopher]

- **Third part : What is being observed in social sciences ?**

1. Traces of Babylonian accounting [G. Chambon, historian]
2. Common observables to History and material science? [L. Bertrand, physicist]
3. About the "Musical triangle": score * performance * perception [F. Nicolas, musicologist and composer]

- **Fourth part: Algorithms and diagrams**

1. Observables and big data [S. Abiteboul, mathematician]
2. The experimental detection at Cern [L. Chevalier, physicist]
3. Tacit knowledge and diagrams [J.-L. Ermine, expert in knowledge management]
4. Quantum observables from many-body diagrams [M. Drissi, physicist]

V. SCHEDULE

Monday 18	Tuesday 19	Wednesday 20	Thursday 21	Friday 22
09h15 Accueil				
09h30 Bontems	09h30 Rosaler	09h30 Chambon	09h30 Balian	09h30 Abiteboul
10h30 Coffee break				
11h00 Bontems	11h00 Moutarde	11h00 Bertrand	11h00 Grinbaum	11h00 Chevalier
12h00 Klein				12h00 Ermine
12h45 Lunch	12h00 Lunch	12h00 Lunch	12h00 Lunch	13h00 Lunch
14h00 Bontems	14h00 Ladyman	14h00 Nicolas	14h00 D'Ariano	14h00 Drissi
15h00 Coffee break				
15h30 Sauvage	15h30 Lorcé	15h30 End	15h30 Roberts	15h30 End
16h30 End	16h30 End		16h30 End	